Investigation of the relation between variations of the $PM_{10}$and $PM_{2.5}$ concentrations and meteorological parameters in dust mission hazard to the south west region of the Caspian Sea (Rasht city)

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Abstract

The South-west region of the Caspian Sea has been repeatedly faced with hazardous dust phenomenon, during last decade. To determine the environmental impacts of the atmospheric systems on dust emission into the region, hourly averages variations of aerosols, PM_{10} and $PM_{2.5}$ and their relationship with some atmospheric parameters such as temperature, relative humidity and horizontal visibility were examined utilizing data from air pollution monitoring stations and airport synoptic-upper level station between May 2011 and December 2013. Spatial distribution or variation of Aerosol Optical Depth (AOD) along with visible images of Terra (or Aqua) has been used to monitor the dispersion of dust over southwest region of Caspian Sea and its coastal area. The results show that hourly average of ambient air pollutants, PM_{10} and $PM_{2.5}$ concentrations are reached to their maximum at 2:00 am LST[2] and follow a decreasing trend through the day. It may be concluded that the concentrations of ambient air pollutants, PM_{10} and $PM_{2.5}$ variation happen in reverse direction with respect to temperature. Another conclusion may draw from different direction of changes between ambient air pollutants, PM_{10} and $PM_{2.}5$ concentrations and temperature is that they mainly come from local sources. These conditions also may be interpreted as an indication of the atmospheric boundary layer evolution and its turbulence role in the dispersion of ambient air pollutants, PM_{10} and $PM_{2.5}$ to deeper atmosphere. They result in their dilution Compared with dust free conditions; it was observed that PM_{10} and $PM_{2/5}$ concentrations have increased by 37% and 17%, respectively. Study upon the relationship between horizontal visibility and relative humidity and particulate maters concentrations was done by means of simple linear regression method. Results showed strong linear relationship between the former and particulate matter concentration. To study the impact of atmospheric instability on the particulate matter concentration and dispersion some available indices were examined, among them Showlter index identified as the most appropriate index in this matter. Study on the horizontal wind showed strong southerly and southwesterly in the lower troposphere accompanied the dust events. Moreover, warm advection was observed during the dust events over the city of Rasht.

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[2] Local Standard Time

Keyword: south-west region of the Caspian Sea, dust emission, concentration of aerosol, atmospheric parameter, R^2

1 Introduction

Atmospheric pollutants are classified into two main groups, particulate and gaseous. The majority of gaseous pollutants are invisible but solid and liquid particles, based on their physical size and characteristics may be seen without it (Sharie Poor and Bidokhti, 2012). Particulate matters (PMs) may be originated from different sources and consequently will have different physical and chemical characteristics. PMs may enter into the atmosphere from various natural sources such as deserts, sea, volcanic eruption that mainly identified as primary pollutants or from anthropogenic sources. Secondary PMs may also be formed in the ambient air following chemical or photochemical processes. These particles, depending on the dominant atmospheric circulation pattern and their weight may reside in the atmosphere for several weeks. Consequently, the seasonal and daily patterns of pollutants in different areas will not be the same (Sharie Poor, 2012). According to the World Health Organization (WHO), 500,000 people are facing premature deaths as the consequences of exposure to particulate matters found in the atmosphere, and increased heart and respiratory attacks impose huge cost on the health and hygiene department .

In terms of size, particulate matters with diameters less than 10 microns are divided into two groups of large (particles diameter between 2.5 and 10 microns) and small (particles diameter less than 2.5 microns. Larger particles include dust and solid or liquid particulate matters originated b) particles y mechanical and attritional activities. While the smaller particles (PM2.5) can resulted from processes such as cars combustion and can penetrate deeper inside the respiratory system (Khodarahmi et al., 2013). Atmospheric pollutants' concentrations may increase or decrease under different atmospheric circulation patterns and their dynamic and thermodynamic characteristics. Turbulent dissipation is another effective, meteorological condition dependent mechanism in reduction of the concentration of pollutants in the ambient air. In this context, the relationship between dynamic and thermodynamic characteristics of the atmosphere, such as heat and momentum fluxes and the issue of pollutants emission have been examined by a Vakili and Bidokhti (1999) and also the turbulence structure of atmosphere's surface layer in pollution emissions, vertical changes in potential temperature in the boundary layer at night and day in Tehran were studied by Ghasami et al. (2010). Hossein Pour (2011) studied the air pollution in Tehran with emphasis on the presence of particulate matter by synoptic approach. Sedaghatkerdar (2003) indicated that the statistical models are appropriate tools for short-term prediction of sulfur dioxide concentration, pollutants emissions control, analysis urban air pollutants. He calculated the linear relationship between concentration of nitrogen dioxide, wind speed and direction and showed that the concentration of pollutants decreases with increasing the wind speed.

According to available statistics, it seems dust as one of the hazardous weather phenomena in the South coast of the Caspian Sea, which its frequency is increasing in the region especially during the last ten years (oskoiee et al., 2013). My suggestion: Recent observations suggest that dust is turning to a hazard in the city of Rasht. The importance of the subject will be better realized

when considering the city climatic condition. Rasht receives, on average, some ….mm of rainfall every year. In this study, for the first time, the changes in the concentrations of PM10 and PM2.5 particles in the Rasht city ambient air were examined during dust events and their relationships with some meteorological quantities, such as temperature, humidity, horizontal visibility and wind speed were examined.

2.1 The study region

Rasht, the capital of Guilan province, is located in 49˚ 35' 45" E and 38˚ 16' 30" N in Guilan central plane at a height of 5 meters above mean sea level (Fig1). The city area is about 102400000 km^2. . Because of its neighborhood with the Caspian Sea, the world's largest lake, its vicinity to the Alborz and Talesh mountains, and its exposure to migrant weather systems, the city receives considerable precipitation give a number during the year and has a mild and highly humid climatic condition. City development in recent decades causes ambient air pollutants' concentrations increase substantially According to the recent population census statistics, Rasht by a population of 700,000 people is the tenth most populated city in Iran. The city population reaches to 1 million during the day, when people from its suburbs travel to the city.

Table1. changes in Rasht area

year	1941	1966	1986	1993	2006
Area(Hectar)	406	950	2994	9250	10240

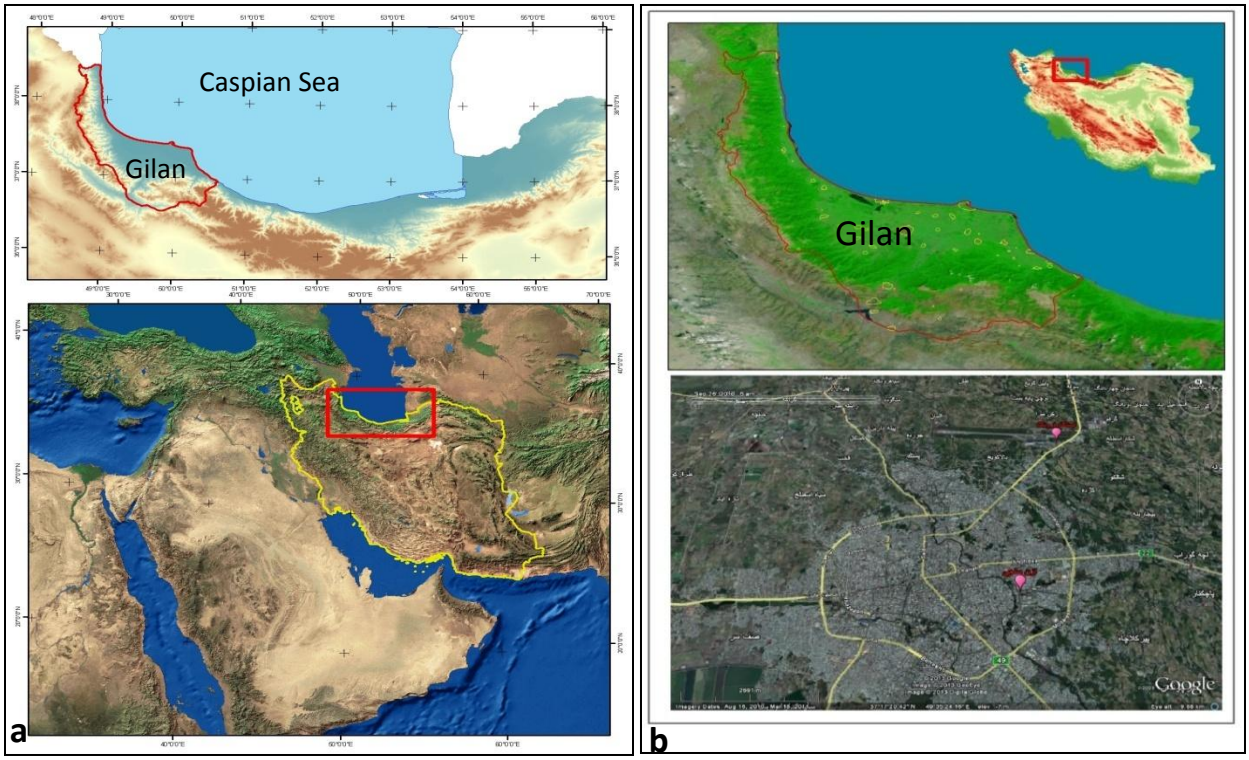

Figure 1. (a) Location of gilan plain**, (b**) Location of Rasht airport synoptic station and pollution monitoring station in Department of environment of Guilan

2.2 Data and Methods

In order to achieve the goals set in the past sections the following data were used:

- PM_{10} and $PM_{2.5}$ data of Environmental Pollution monitoring station of Rasht office of Department of Environment (DOE) that were received at 1-hour intervals for the period of 5 May2011 to the end of 2013 (the whole duration of its activity).

- To determine the days with dust events in the area, SCDATA group 7 with at least one report of suspended dust, code 06, were reviewed. Accordingly, 16 days identifies with dust events.

- Daily Visible Image of MODIS sensor on Terra or Aqua satellites to confirm the occurrence of reported dust events.

- Meteorological variables such as temperature, relative humidity and horizontal visibility. The data on these variables were belonging to Rasht airport synoptic station which is the closest weather station to the Rasht pollution monitoring station (Fig.1 b).

- The measured data was received from upper level station of Rasht airport which launched from 2007 as the first upper air station of northern coast of the country. This data includes measuring the quantities of temperature, pressure, wind direction and velocity, latitude and longitude, height above sea level, dew point temperature, geopotential height and relative humidity at different

levels of the atmosphere with gd format which has been sent data for 8-second intervals using GRAWMET software.

3 Results and Discussion

In Table 2, classification of air quality based on concentrations of two indexes, PM_{10} and $PM_{2.5}$ is provided by the Environmental Protection Agency of America (EPA). For dusty days during the statistical period that the environment SA data are available, a total of 371 sampling during 16 dusty days (average of 23 measurements per day) has been registered. During this period, variations of PM_{10} were between 6.3 μg·m-3 to 218.99 μg·m-3 and its average was 70.85 μg·m-3 and variations of $PM_{2.5}$ were between 3.72 μg·m-3 to 140.07 μg·m-3 and its average was 47.88 μg·m-3. Meanwhile (Figures 2, 3), in 181 measured cases, 48.7% of sampling within 15 dusty days, PM_{10}concentration was in the range of moderate pollution and in 18 sampling cases (4.8%) in the 5 dusty days, it was at unhealthy for sensitive groups. In 144 measured cases, 39% of sampling within 15 dusty days, $PM_{2.5}$ concentration was in unhealthy range for sensitive groups and in 92 sampling cases (25% of cases) in the 14 dusty days, it was at unhealthy range (Fig2,3). Figure4 shows variations of 3-hourly $PM_{2.5}$ and PM_{10} in dusty conditions have similar trends.

Table 2. Daily PM_{10} and $PM_{2.5}$ pollutants based on EPA standards,2012.

Air quality	good	moderate (relative healthy)	Unhealthy for sensitive groups	Unhealthy	very unhealthy
Color	Green	Yellow	Orange	Red	Purple
$PM_{10}(\mu gm^{-3})$	**0-54**	**55-154**	**155-254**	**255-354**	**>355**
$PM_{2.5}(\mu gm^{-3})$	**0-12**	**12.1 - 35.4**	**35.5-55.4**	**55.4-150.4**	**> 150 .5**

Table 3. variations of pollutants concentration

	$PM_{10}(\mu gm^{-3})$	$PM_{2.5}(\mu gm^{-3})$
Average	70.85	47.88
Minimum	6.3	3.72
Maximum	218.99	140.07

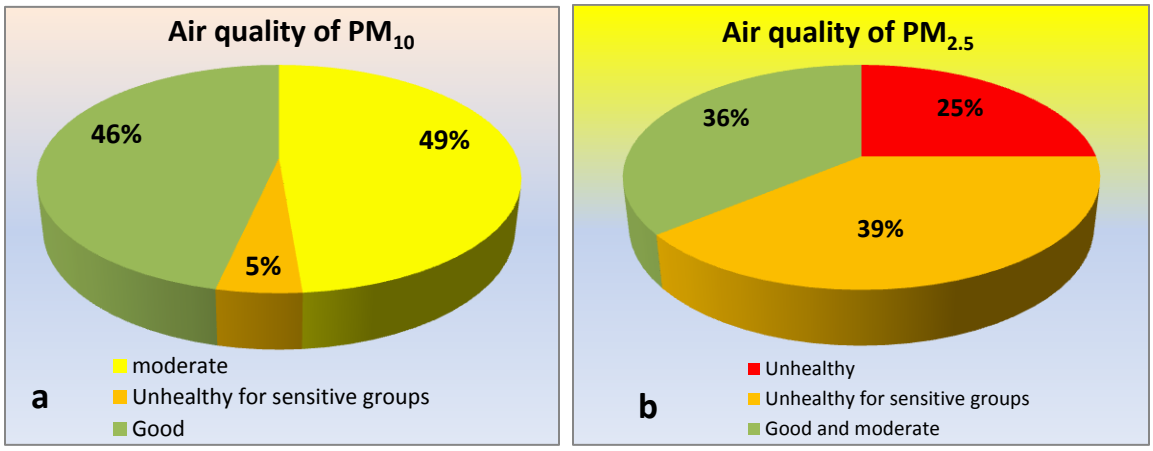

Figure 2. **a** variations of air quality (%) based on PM_{10}, **b** variations of air quality (%) based on $PM_{2.5}$ index, for Rasht station

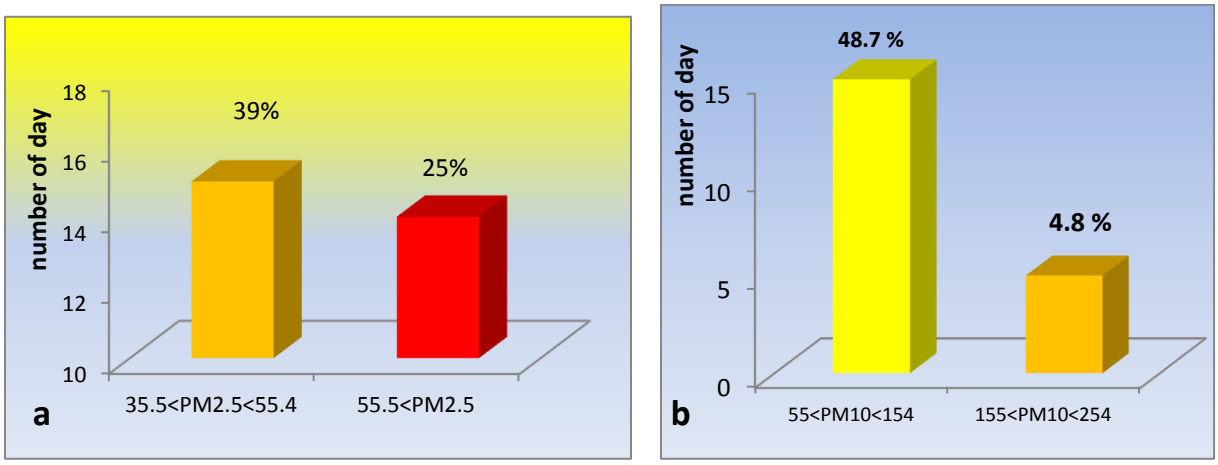

Figure 3. daily frequency of concentration variation, **a** $PM_{2.5}$ pollutant, **b** PM_{10} pollutant

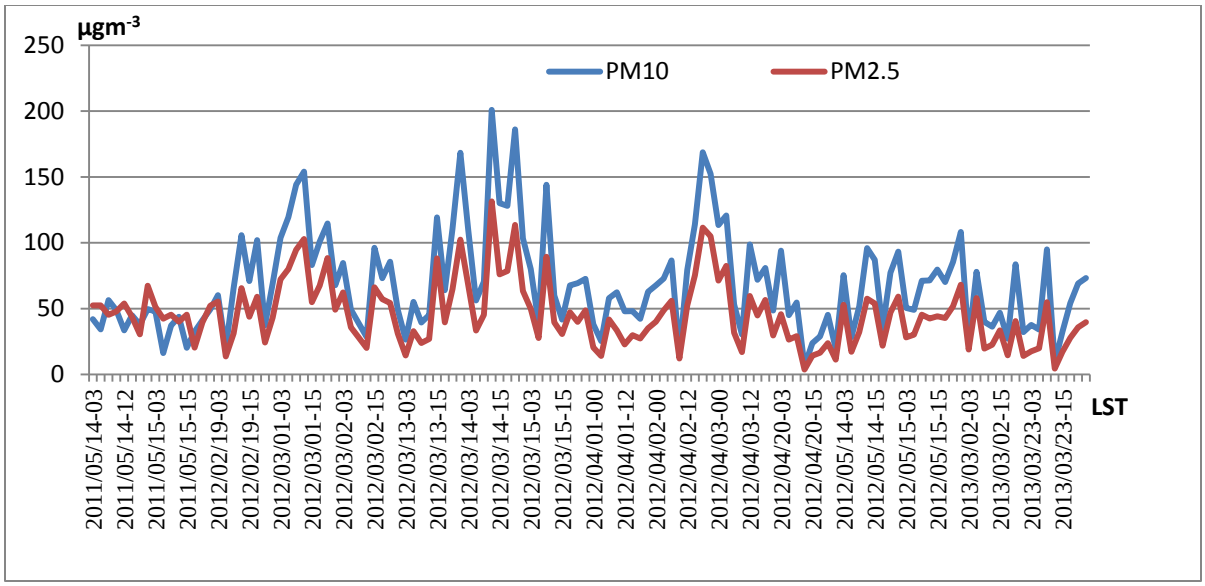

Figure 4. 3-hourly $PM_{2.5}$ and PM_{10} in dusty conditions

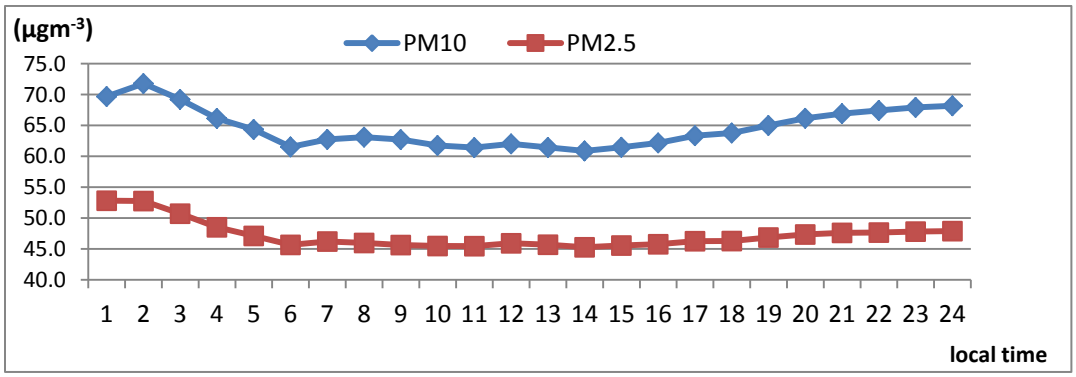

Figure 5. daily averages of pollutants in dusty conditions

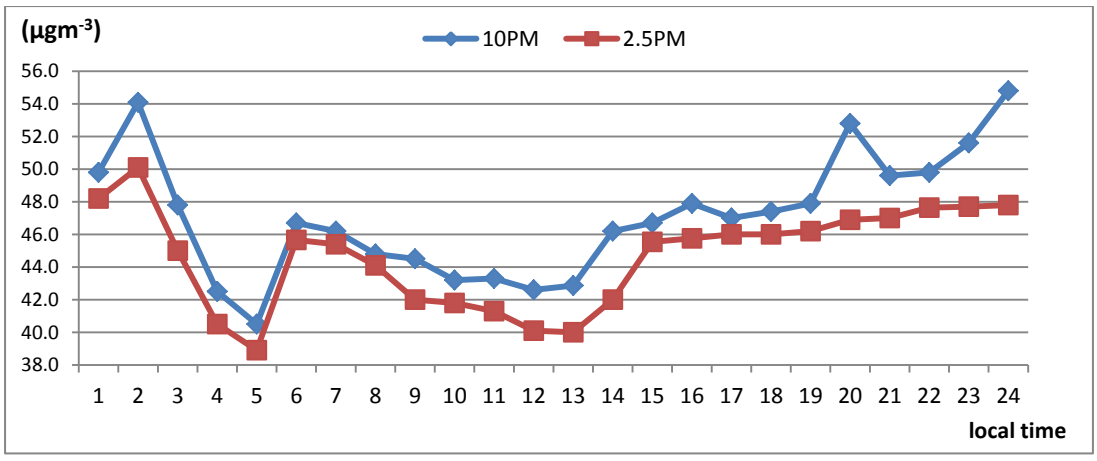

Figure 6. Daily average of pollutants in dust-free conditions

Daily average of PM_{10} and $PM_{2.5}$ pollutants concentrations in dusty conditions showed that their daily variations were relatively similar to each other (Fig5). On average, two minima at 05:00 and 13:00 and two maxima at 00:00 and 02:00 of local standard time (LST) were observed in free-dust conditions (Fig6). Compared with dusty conditions, PM_{10} concentrations showed reductions between 19.6% and 37% and $PM_{2.5}$ concentrations showed reductions between 0.6% and 17% during dust-free conditions (Table 4). In other words, PM_{10} concentrations variation were greater than $PM_{2.5}$ concentrations in dust emission conditions (Fig7). The greatest difference of $PM_{2.5}$ concentration between dusty and dust-free conditions is related to hours of 5 AM and 12 noon and its lowest difference is related to 7 PM to 12 midnight (Fig8).

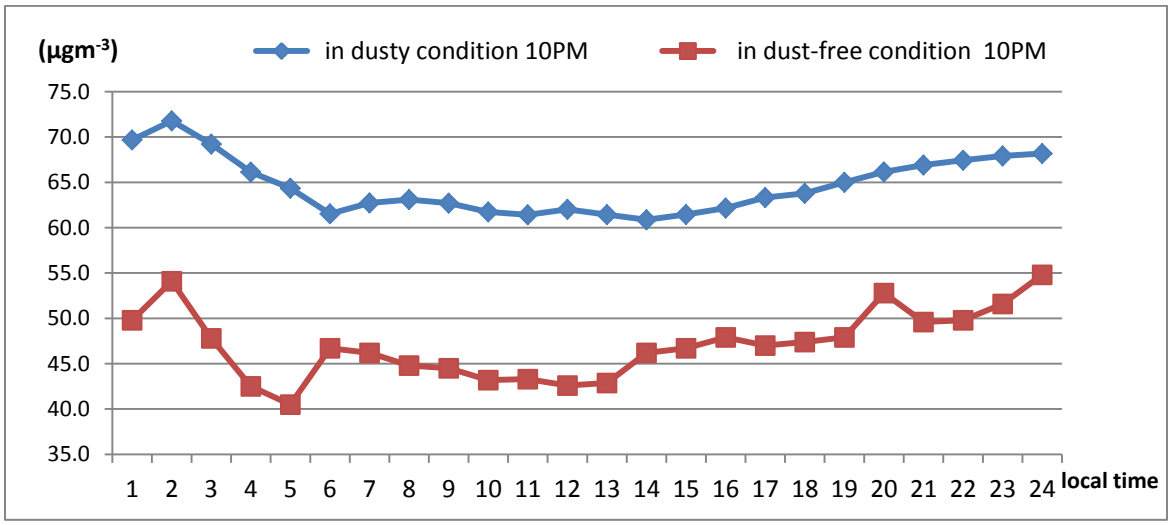

Figure 7. Ensemble average of PM_{10} pollutants in dusty and dust-free conditions

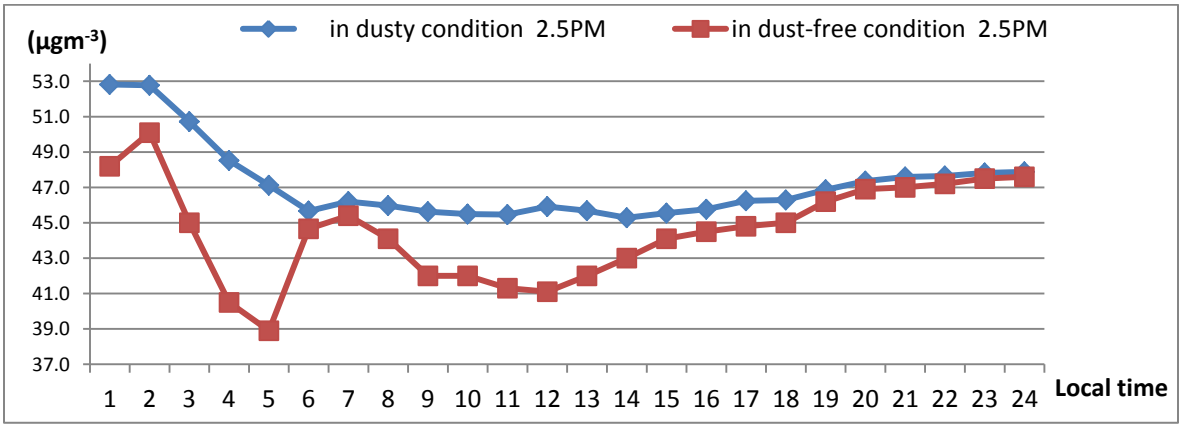

Figure 8. Ensemble average of $PM_{2.5}$ pollutants in dusty and dust-free conditions

Table 4. reduction percentage of hourly average of PM_{10} and $PM_{2.5}$ pollutants

Hour	Reduction of PM_{10}(percent)	Reduction of $PM_{2.5}$(percent)	Hour	Reduction of PM_{10}(percent)	Reduction of $PM_{2.5}$(percent)
1	**19.6**	**8.7**	13	**26.3**	**8**
2	**20**	**5**	14	**26.3**	**5**
3	**22.9**	**11.3**	15	**28.5**	**3.2**
4	**24**	**16.5**	16	**29**	**2.8**
5	**24**	**17.4**	17	**29**	**3.1**
6	**24**	**2.2**	18	**29.5**	**2.8**
7	**24**	**1.7**	19	**30**	**1.4**
8	**24.6**	**4**	20	**30**	**0.9**
9	**25.6**	**7.9**	21	**30.9**	**1.24**
10	**25.7**	**7.6**	22	**31.3**	**0.9**
11	**25.8**	**9.1**	23	**35.7**	**0.7**
12	**26.1**	**10.5**	24	**37**	**0.6**

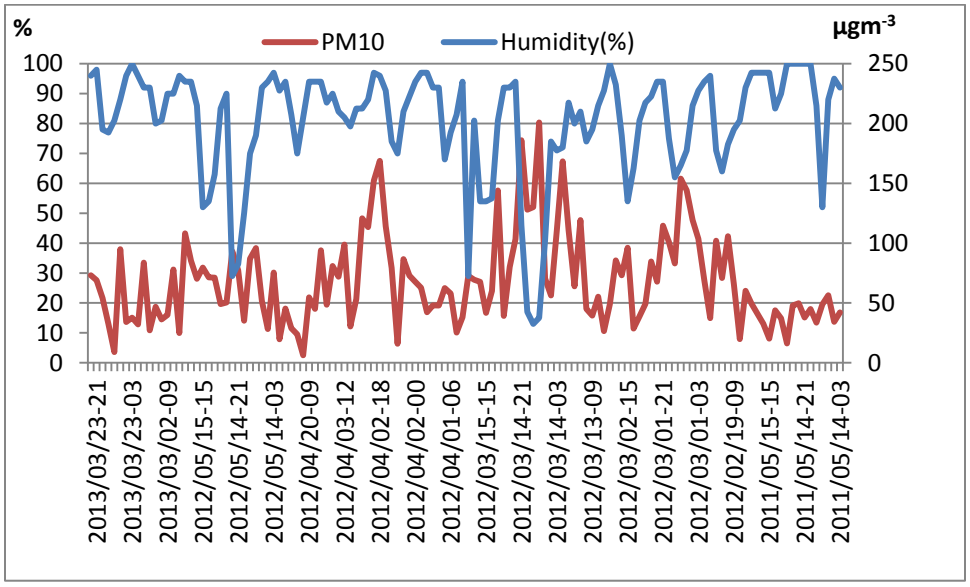

Figure 9. 3-hourly variations of relative humidity and PM_{10} concentration.

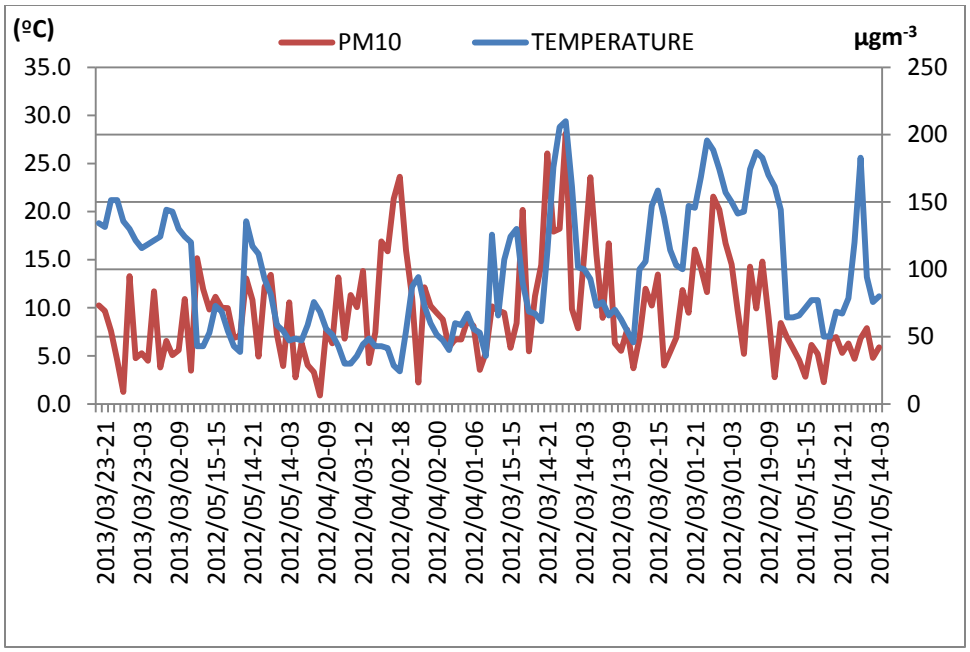

Figure 10. 3-hourly variations of temperature and PM_{10} concentration

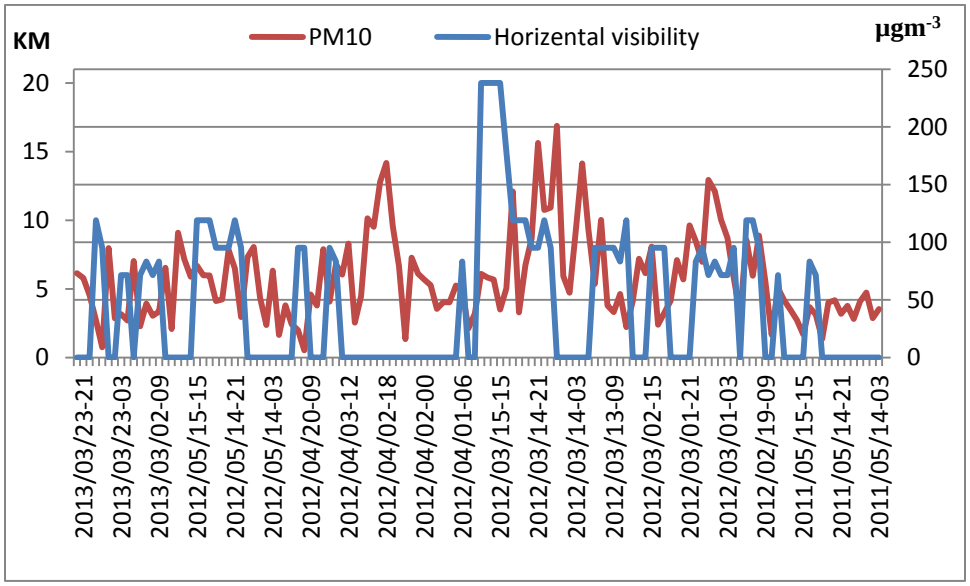

Figure 11. 3-hourly variations of horizontal visibility and PM_{10} concentration

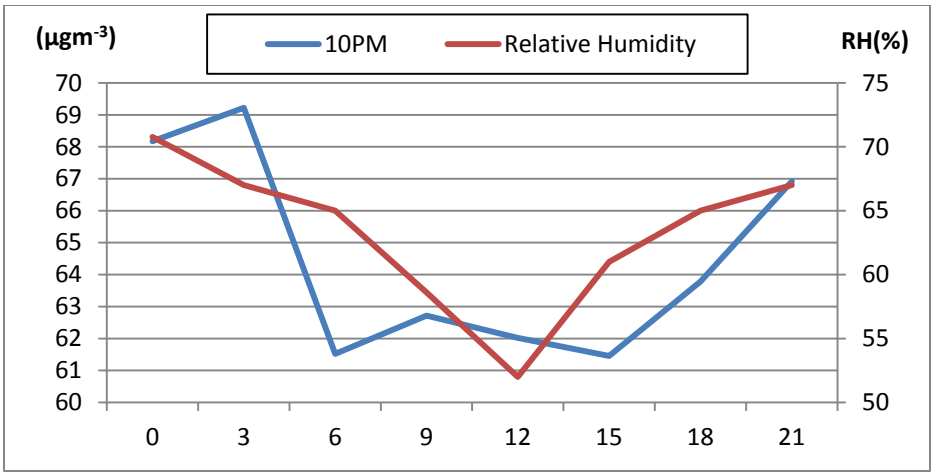

Figure 12. Hourly average variations of relative humidity and PM_{10}

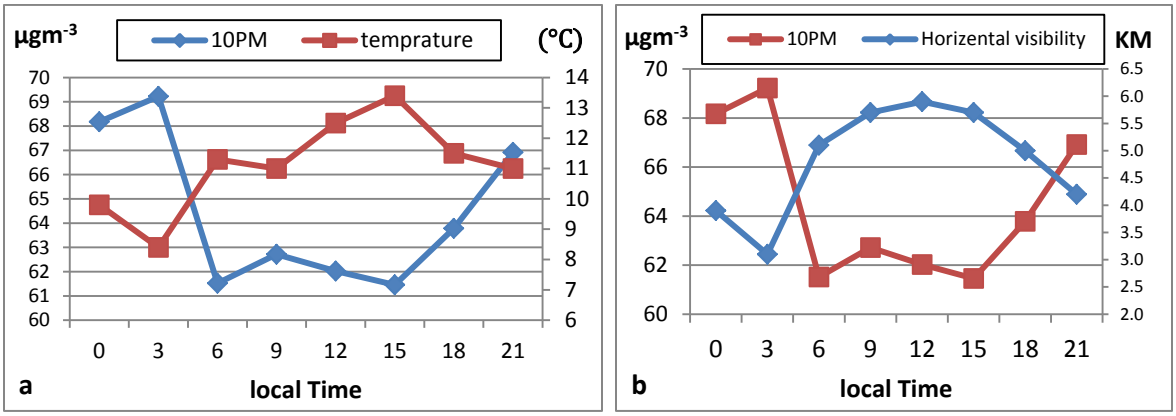

Figure 13. a Comparison between ensemble averages of temperature and PM_{10} concentration, **b)** Comparison between ensemble averages of horizontal visibility and PM_{10} concentration.

Hourly averages variation of relative humidity for dusty days (Fig. **12**) shows that its maximum has happened at 00:00 LST (70%) and its minimum at 12:00 LST (52%) and in comparison with the two quantities of temperature and horizontal visibility, its trend of variations has less correlation with aerosols concentration variations and alternately experiences positive and negative correlation during night and day (Table 5). Especially during 3 PM to 9 PM, along with increasing the concentration of particulate matter, relative humidity also follows an increasing trend. It seems that in this period, liquid particulate matters compared the solid ones have allocated greater share among the aerosols (PM). In other words, in these hours of day, primary aerosols caused by dust emission to the area, compared with secondary aerosols caused by industrial pollution, vehicles traffic and human activities with local origins, have less role in increasing the concentration of particulate matter. Investigation of the wind speed variations indicate that an increase in PM_{10} concentration is highly dependent on less than 2 meters per second wind speed and calm wind conditions and the continued stability of the atmosphere. In other words, during this time, calm winds and winds with less than 2 meters per second speed

have the highest frequency of occurrence and the highest hourly correlation of the two quantities is in 12 midnight.

hourly average variations of horizontal visibility for dusty days (Fig. 13b**)** indicate that its maximum is on 12 AM(3.1 Kilometers) and its minimum is on 12 noon(5.9 Kilometers). It has increasing trend during 03 AM to 12 AM and decreasing trend during 12AM to03 AM. With increasing of PM_{10} concentration, especially during night, horizontal visibility decreased and with decreasing of PM_{10} concentration, especially during day that Mixing depth increases, horizontal visibility increased (Table 5). In the other hands, In the other hands, they have reverse trend and the most hourly correlation is on 03AM and Similarly, for temperature, Decreasing trend of particular matters during day, indicates impact of temperature increasing on Turbulent mixing Obviously (Fig. 13a) .

Table 5. Hourly average correlation of PM_{10} with hourly average of parameters: horizontal visibility, temperature and wind

Hour	0	3	6	9	12	15	18	21
Horizontal visibility with PM_{10}	-0.84	-0.87	-0.69	0.78	-0.72	-0.69	-0.83	-0.85
Relative humidity with PM_{10}	-0.72	-0.82	0.6	-0.69	0.62	-0.71	0.68	0.72
Temperature with PM_{10}	-0.81	-0.8	-0.78	-0.83	-0.81	-0.86	-0.64	-0.69
Calm winds (less than 2 meters per second speed) with PM_{10}	0.86	0.81	0.72	0.79	0.84	0.73	0.82	0.79

Comparing the hourly average of PM_{10} concentration with the hourly average amount of parameters such as temperature, relative humidity, horizontal visibility and fitting the best graph for these data shows that during a day, horizontal visibility with a strong R^2= -0.89 (Fig. 14) and relative humidity with R^2=0.319 have the lowest correlation with concentration of PM_{10}(Fig. 15). In general, investigation of the hourly average PM_{10} concentration shows that the lowest concentration of particulate matter is related to hours in which the highest temperature, highest horizontal visibility and increased surface wind speed occurs and the highest concentration of aerosols is related to hours that have the lowest horizontal visibility, lowest temperatures, reduced wind speed, atmospheric stability and thus reduced turbulent mixing. Increased relative humidity along with increased concentration of particulate matter during the evening and night that are inconsistent with the change of other meteorological parameters suggests that the role of secondary aerosols caused by human activities in increasing the pollution is important, along with primary aerosols which are emitted to the area with middle-scale and large-scale flows

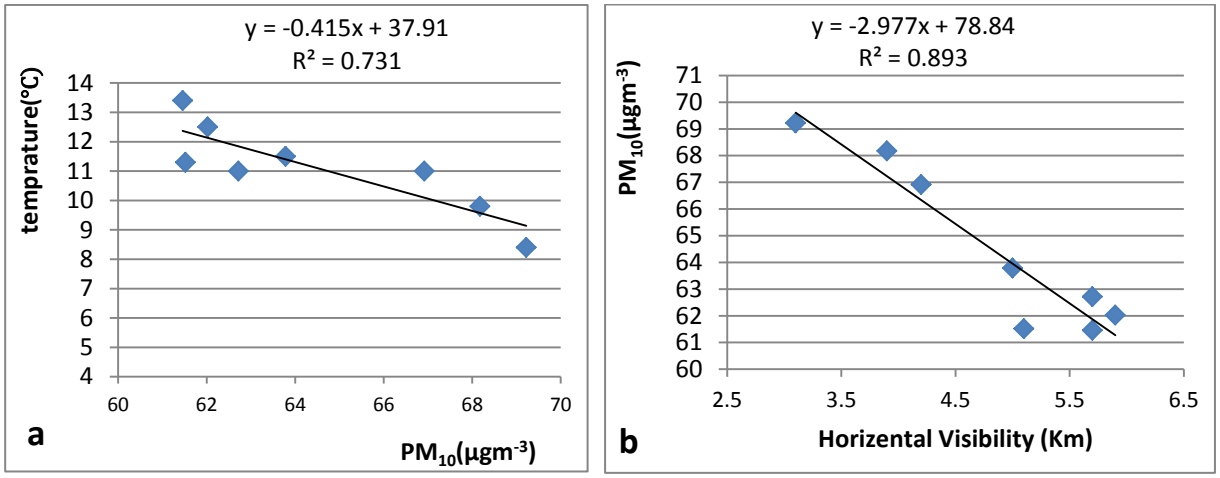

Figure 14. a fitted graph on hourly average of temperatures and hourly average of PM_{10} concentration, **b** fitted graph on hourly average of horizontal visibility and hourly average of PM10 concentration

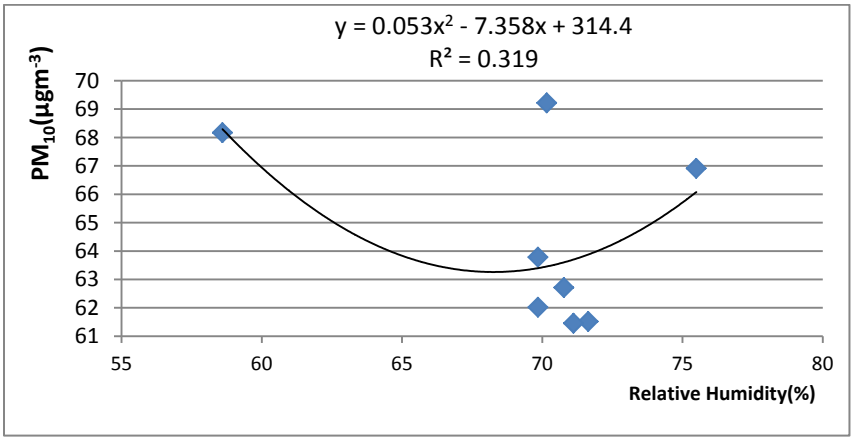

Figure 15. fitted graph on hourly average of relative humidity and hourly average of PM_{10}

3.1 Remote Sensing Analysis

Examination of daily MODIS sensor visible band images of Terra and Aqua satellites showed that the dust is mostly penetrating to the southern coast of the Caspian Sea from sources located outside the region. For example, MODIS images of 14 May 2013 and 20 April 2012 show that dust enrouted from the Iran central plateau to the region of the study through the Sefidroud valley (Manjil gap) (Fig. 16). Spatial zoning of atmospheric optical depth (AOD) index also indicated the optical depth had its highest amount over the western half of Iran through the southwestern coast of the Caspian Sea and the northern part of the Alborz Mountain range (Fig. 17).

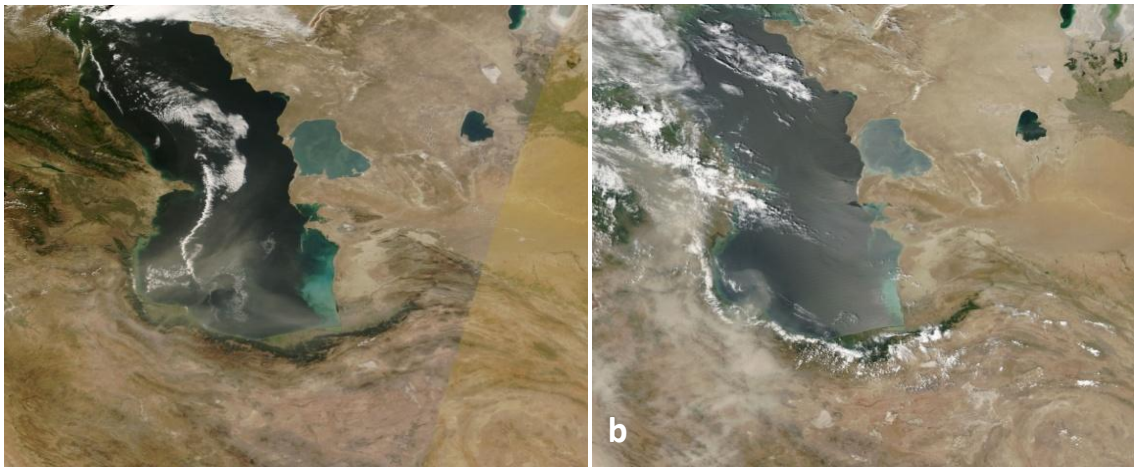

Figure 16. Images of MODIS sensor visible band on Terra satellite, **a** April 20, 2012

b May 14, 2013

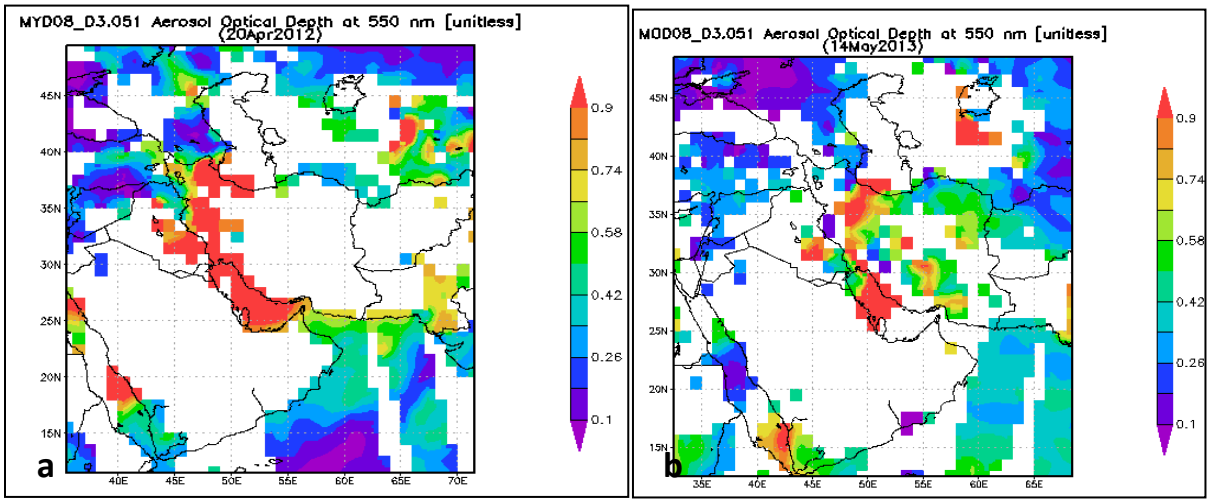

Figure 17. spatial zoning of AOD values on Terra satellite MODIS sensor, **a** April 20, 2012, **b** May 14, 2013.

3.2 Studying the instability indices

In this section for the first time, the atmosphere conditions such as vertical profiles of temperature and humidity fields, vertical profiles of wind field and variations of atmospheric instability indices at the time of dust emission to the southern coast of the Caspian Sea were studied. For this purpose the data from upper level station of Rasht which opened from 2007 as the first upper level station of northern coast of the Iran, was used. Unfortunately due to the high cost of providing radio sound, its sending from Rasht airport station has not occurred in a regular and daily manner and releasing it has often occurred at 00:00 UTC with intense precipitation. So there is no regular data for dusty days. Data were extracted during the period of 2007-2013 for the dusty days in which the radio sound release has occurred, and data file were received that

contains measured quantities of temperature, pressure, wind direction and velocity, latitude and longitude, height above ground, dew point temperature, geo potential and relative humidity at different levels of the atmosphere with gd format and have been sent for 8-second intervals, and the measured data were displayed using GRAWMET software as a text file, the SKEW-T Graph was simulated and the instability indices was calculated (Table. 5). In all the above days, temperature inversion can be seen in layer near the surface of lower troposphere that in some cases this inversion has considerable intensity. Under these conditions, mainly the depth of inversion layer is limited under the 900 hPa. In some cases, the depth of reverse layer has extended near the 850 hPa (Table. 6). Temperature inversion has the key role in air pollution because it causes atmospheric stability and thus the stability against vertical movement of pollutants. It also damps the wind energy and prevents vertical and horizontal dispersion of pollutants. Air pollution reaches to its most intense amount when the temperature inversion is established with low altitude and long sustainability.

Table 5. instability indices of upper level station in Rasht airport during dusty days.

Date	LI	CAPE	TTI	KI	showlter
2013.03.23	8	0	50	19	1
2012.05.14	-6	1652	50	24	1
2012.04.02	7	0	49	26	2
2012.03.14	13	0	48	25	2
2012.03.13	16	0	44	6	5
2012.03.01	5	0	56	24	0
2012.02.29	4	0	51	19	1
2011.06.12	-6	1312	48	25	0
2009.05.06	3	0	45	23	4
Average	4.9	329	49	21.2	1.8
Instability conditions	LI <0		44 < TTI <50 Convection is possible	KI>25	SW<0
Stability conditions	LI>=0		TTI<44	KI<25	SW>4

Table 6 values of meteorological quantities recorded by radio sound in upper level stations of Rasht during dusty days

Date	Wind direction in surface	wind direction of 850 hPa	wind direction of 700 hPa	wind direction of 500hPa	Surface pressure (hPa)	Surface temperature (°c)	pressure on top of inversion layer (hPa)	Temperature of inversion layer (°c)	°c/10hpa
2013.03.23	189	195	210	212	1001	9.6	950	24	2.8
2012.05.14	190	99	223	225	1007	20.8	914	22.2	0.1
2012.04.02	320	185	196	236	1015	13.8	992	17.6	1.6
2012.03.14	184	237	230	248	1003	6.8	935	20.9	2
2012.03.13	152	229	261	263	1015.7	4.6	886	12.9	0.6
2012.03.01	223.5	206	232	242	1005	6.2	890	8.6	0.2
2012.02.29	234	219	224	225	999	12	978	20.7	4
2011.06.12	270	306	257	221	1006	23.2	1000.8	23.4	0.3
2009.05.06	60	315	260	265	1010.8	16.8	987	20.8	1.6
average	220.3	209.5	232.5	237.4	1006.9	12.6	948	19	1.46

4. Conclusion

Increasing of dust generation sources and availability of dust rising conditions and its emission in recent decades led the dust phenomenon as one of the most important atmospheric phenomena reduced air quality. Dust emission to the northern slopes of the Alborz mountain (south of Caspian Sea) is a new phenomenon that could affect the amount of particulate matter in the air especially $PM_{2.5}$ and PM_{10}. Therefore, the behavior of PM_{10} and $PM_{2.5}$, and their relationship to variations of atmospheric parameters such as temperature, relative humidity and horizontal visibility were studied using pollution monitoring station data of Rasht and Rasht airport synoptic station and also the Rasht airport upper level station Obtained results are as follows:

1. For dusty days, in 48.7% of sampling, PM_{10} concentration was in the range of moderate pollution and in 4.8%, it PM_{10} concentration was in the unhealthy range for sensitive groups. In 35% of sampling cases, $PM_{2.5}$ concentration was in unhealthy range for sensitive groups and in 21% of cases, it was in the unhealthy range.
2. Both daily average variations of PM_{10} and $PM_{2.5}$ in dusty conditions were the highest values in 2 AM. It will experience a decreasing trend from 2 AM to 6 AM in local time and an increasing condition from 3 PM to 12 midnight. For dust-free conditions, regardless the significant decrease in PM_{10} concentration and hourly fluctuations, many similarities between oscillatory behaviors of these two pollutants variations can be seen during the day with dusty conditions. On average, two minimum for 5 AM and 1 PM and two maximum for 2 AM and 12 midnight in local time can be seen.
3. For dust-free conditions, the concentration of PM_{10} is reduced between 19.6% to 37% and the concentration of $PM_{2.5}$ index reduced between 0.6% to 17% compared to dust emission conditions. In other words, the concentration of PM_{10} compared to variations of $PM_{2.5}$ has greater dependence and be influenced from dust emission conditions. The greatest difference between $PM_{2.5}$ concentration in both dusty and dust-free conditions is related to 5 AM and 12 noon and the lowest difference is in 7 PM to 12 midnight.

4. Hourly Average of horizontal visibility for dusty conditions fluctuate between 3.1 Km in 3 AM of local time and 5.9 Km in 12 noon. Comparing the hourly average changes of this quantity with hourly average changes in PM_{10} concentration shows that by increasing the aerosols and PM_{10} concentration especially during night, horizontal visibility is reduced and by reducing the amount of particulate matter, especially during day which mixing depth increased, horizontal visibility is increased. In other words, variations of horizontal visibility and PM_{10} concentration are reversed and the correlation between them is negative. Temperature variations also show a similar trend with the PM_{10} concentration. The reducing trend of aerosols concentration during day reveals the impact temperatures increasing on turbulent mixing. During the afternoon and evening, increasing of particulate matter, caused relative humidity also to follow increasing trend. Compared with the two quantities of temperature and horizontal visibility, trend variations of relative humidity has less correlation with concentration variations of aerosols and alternately experiences positive and negative correlation during night and day. In other words, primary aerosols caused by dust emission to the area, have less role in increasing the concentration of particulate matter compared with secondary aerosols caused by industrial pollution, vehicles traffic and human activities with local origins.
5. Survey of the wind speed variations indicates that increase of PM_{10} concentration is highly dependent on wind speed less than 2 meters per second and calm wind conditions and the stability of the atmosphere. In other words, during this time, calm winds and winds with less than 2 meters per second speed have the highest frequency of occurrence and the highest hourly correlation of these two quantities is on 12 midnight.
6. Comparing the hourly average of PM_{10} concentration with the hourly average of parameters such as temperature, relative humidity and horizontal visibility and fitting the best chart on data indicate that during the day, horizontal visibility with R^2= - 0.89 and relative humidity R^2= 0.319 have the highest and lowest correlation with the concentration of PM_{10}, respectively.
7. Increasing of relative humidity with increasing of particulate matter concentration during the evening and night hours that are inconsistent with the variation of other meteorological parameters suggests that the role of secondary aerosols caused by human activities in increasing the pollution is important, along with primary aerosols which are emitted to the area with middle-scale and large-scale flows.
8. Spatial zoning of daily average of optical depth index (AOD) resulting from MODIS sensor measurement in 550 nanometers band and with horizontal resolution of 1°×1° also indicate the expansion of high optical depth amounts from the western half of the Iran to southwestern coast of the Caspian Sea and the northern part of the Alborz Mountains.
9. Vertical profile of wind in skew-t chart of Rasht airport upper level station, in most cases shows the dominance of the southern and southwestern strong currents in the depth of troposphere. In addition, the vertical arrangement of the wind in middle troposphere and the wind field retreat with height indicates the warm advection in the area at the time of the phenomenon occurrence.

References

- Aliakbari Bidokhti A.A, Shareipoor Z (2009) Meteorological conditions top atmospheric and acute situation air pollution (case study: Tehran). Journal of Environmental studies. 35 (52):1-14
- Azizi Gh, Shamsipoor A, Miri M, Safar raad T (2012) Statistics-Synoptic analysis dust phenomena in western half of Iran. Journal of ecology. 38(3): 123-134
- Bidokhti A.A, Shareepoor Z (2003) Investigation of variation of surface ozone around geophysicists institute synoptic station in 2002. Journal of Ecology. 42:63-74
- Costa S, Mezzasalam P, Levizzani V, Alberoni P.P, Nanni S (2001) Deep convection over Northern Italy: synoptic and thermodynamic analysis. Atmos. Res. 56: 73-88
- Czys R.R, Scott R.W (1993) A simple objective method used to forecast convective activity during the 1989 PACE cloud seeding. Journal of App. Meteorol. 32: 996-1005
- Dosio A, Arellano J.V-G.D, Holtslag A.A.M (2005) Relating Eulerian and Lagrangian Statistics for the Turbulent Dispersion in the Atmospheric Convective Boundary Layer. Meteorology and Air Quality Section, Wageningen University, Wageningen, Netherlands.1175-1191
- Ejlali, F (2007) Air pollution, publication of agriculture education.
- Gasami T, Aliakbari Bidokhti A.A, Sedaghatkerdar A, Sahraiean F (2007) Study of Synoptic conditions at several critical period the air pollution in Tehran. Environmental Science and Technology. 9 (3): (Serial34), 229-238
- Gasami T, Aliakbari Bidokhti A.A, Sedaghatkerrdar A, Sahraeian F (2010) Assessing vertical changes of potential temperature at several critical period of air pollution in Tehran. Environmental Science and Technology 11(3): 13-23
- George J.J(1960) Weather Forecasting for Aeronautics. Academic Press, New York. 673 pp
- Ahmadi Givi F, Sabetghadam S (2006) Study of sensitivity of the meso-scale model MM5 schemas using MRF and Eta-Mellor-yamada for estimate the depth of the urban mixed layer. Conference on Numerical Weather Prediction
- Hoseinpoor Z (2011) Synoptic analysis of air pollution in Tehran (emphasis on suspended particles PM_{10}), MS Thesis, Department of Geography, Tehran University
- Hurley P (2007) Modeling mean and turbulence fields in the dry convective boundary layer with the eddy-diffusivity/mass-flux approach. Boundary-Layer Meteorol. Soc. 125:525–536
- Hurley P (2008) TAPM V4. Part 1: Technical Description, CSIRO Marine and Atmospheric Research Paper No. 25
- Hurley P (2008)TAPM V4. User Manual", CSIRO Marine and Atmospheric Research Internal Report No. 25
- Jakob C, Siebesma A (2003) A new subcloud model for mass-flux convection schemes: Influence on triggering, updraft properties and model climate. Mon Wea Rev 131:2765–2778
- Krauss T.W, Santos J.R (2004) Exploratory analysis of the effect of hail suppression operations on precipitation in Alberta, Atmos. Res, 71:35-50
- Krishna M (2008) Study of the Intensity of Super Cyclonic Storm GONU Using Satellite Observations, J: Applied Earth Observation and Geoinformation.
- Leili M, Naddaffi K, Nabizadeh R, Yunesian M, Mesdaghinia A, Nazmara SH (2010) Study of particle'concentration and air quality Index in central of Tehran,12'th National conference in shahid beheshti university, oct2010
- Manzato A, a Morgan G (2003) Evaluating the sounding instability with the lifted parcel theory, Atmos. Res. 67-68: 455-473
- Muller M and et al.(2009) Heavy rains and extreme rainfall-runoff events in Central Europe from 1951 to 2002,Natural Hazards and earth system Sciences 9(2009):441-450
- Nielinger J, Rainer R, Höfl H.C, Kost W(2005) Lagrange VERSUS Eulerian Dispertion Modeling Comparsion For Investigation Concerning Air Pollution Caused By Traffic. 9th Int. Conf. on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
- Peng Wang H.M (2011) Random-walk model simulation of air pollutant dispersion in atmospheric boundary layer in China. Environ Monit Assess. 172: 507–515
- Peng Wang H.M (2011) Random-walk model simulation of air pollutant dispersion in atmospheric boundary layer in China. Environ Monit Assess. 172: 507–515
- Shareipoor Z (2009) Assessing changes Seasonal and daily air pollutants and its relationship with weather parameters. Journal of Physics Earth and Space 2,119
- Sadeghi hosseini A, Rezaeeian M (2007) Investigation of several instability Index and cloud seeding potential Esfahan region. Journal of Physics Earth and Space, 32(20) 8387-98

- Sedaghatkerdar A, Jahangiri Z, Rahimzadeh F (2004) Potential ability of statistics science in meteorological study on air pollution, statistics conference in allameh university, 1-10
- Showalter A.K(1953) A stability index for thunderstorm forecasting. B. Am. Meteorol. Soc. 34: 250-252
- Siebesma A.P, Teixeira J (2000) An advection-diffusion scheme for the convective boundary layer: description 1D results. 14th symposium on boundary layer turbulence, Aspen, Colorado, USA, pp 133–136
- Simoenov P, Georgiev C.G (2001) A case study of tornado-producing storm south of Rhodopes Mountain in the Eastern Mediterranean. Atmos. Res., 57: 187-199
- Simoenov P, Georgiev C.G (2003) Severe wind/hail storms over Bulgaria in 1999–2001 period: synoptic and mesoscale factors for generation. Atmos. Res., **68**, 629–643
- Soares P.M.M, Miranda PM.A, Siebesma A.P, Teixeira J (2004)An eddy-diffusivity/mass-flux parameterisation for dry and shallow cumulus convection. *Quart J Ray Meteorol Soc* 130:3365–3383
- Tajbakhsh S, Ghaffarian P, Mirzaee E (2011) Methods for prediction of thunderstorm'Occurrence, Journal of Physics Earth and Space. 35(4):147-166
- Vakili Gh.A, Aliakbari Bidokhti A.A(1999) Observations of the structure of atmosphere turbulence and its application to the problem of air pollution distribution, MS Thesis, Geophysics Institute of University of Tehran
- Wang J, Christopher S.A (2003) Inter comparison between satlite derived optical thickness and $PM_{2.5}$ mass: implications for air quality studies, Geophys. Res. Lett., 30:2095-2116
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